NESTE OIL

# NExBTL® Renewable Diesel
# Singapore Plant

## TALLOW PATHWAY DESCRIPTION

## 1 INTRODUCTION

Neste Oil is the world’s leading producer of Renewable Diesel with on-line capacity of 2 million metric tonnes per year (2 Mt/a) equivalent to 675 million gallons per annum distributed between among its three world-wide facilities in Porvoo, Finland; Rotterdam, Holland and Singapore. Branded under the name of NExBTL®, this renewable diesel is a fungible, low-carbon, low-emission, paraffinic biofuel. Compared to petroleum diesel, NExBTL® has a higher cetane number and contains no aromatic compounds or sulphur. This translates into superior combustion properties to petroleum diesel.

This report outlines the NExBTL® Renewable Diesel production process as realized in the Neste Oil Singapore facility located at 1 Tuas South Lane, 637301 Singapore using tallow feedstock. The refinery is built in the Tuas Industrial District, around 30 minutes from the centre of Singapore. The refinery is integrated into the area’s existing industrial infrastructure, and makes use of local site utilities and port and storage services.

## 2 FEEDSTOCK SUMMARY

Tallow rendering and supply to the Neste Oil NExBTL® Renewable Diesel (RD) Singapore plant process is described. Tallow is imported from Australia and New Zealand. Shipments vary by source and distance calculated. Rendering energy consumption corresponds to the California low energy rendering process.

This report describes the tallow feed procurement and shipping to the NExBTL® Renewable Diesel production plant located in Singapore in Tuas Industrial District. This data was used to modify the CA-GREET model for the calculation of GHG emissions.

## 3 FEEDSTOCK PROCUREMENT

The animal feed / tallow to the Singapore plant is purchased from rendering facilities in Australia and New Zealand which are transported to the Neste Oil NExBTL® Singapore plant for processing. The ports used are Melbourne, Sydney and Brisbane in Australia and Port Tauranga and Port Auckland in New Zealand.

The animal feed / tallow will be transported from the various ports in Australia to the Singapore plant using an ocean-going vessel over an average distance of 4,548 miles.

## 4 RENDERING PROCESS

When animals are slaughtered to produce meat for human consumption, approximately 50% of the animal is turned into animal by-products. Animal by-products contain edible fats, protein feed used in pet food production, skins, gelatine as well as tallow or animal fat, a rendering component.

In the rendering process, the feedstock is crushed and heated evaporating the water and enabling the fat, which is known as 'tallow' to be separated from the protein or 'greaves'. Temperatures are selected in order to destroy microbes but not to denature the proteins.

Energy consumption in the rendering process is primarily due to steam usage for heating of the animal by-products and for water evaporation. In order to reduce costs from fuel consumption modern rendering plants use waste heat recovery through hot water generation.

Both wet and dry rendering processes are used in Australia and New Zealand

1. In the wet rendering process the tissue is ground to a small particle size of about 12 mm and preheated at around 95°C for about 5 to 60 minutes depending on the individual system. The heated slurry is then pressed or centrifugally separated into liquid and solid phases. The liquid, which consists of lipids (fats) and water, is then centrifugally separated into two streams. The wet solids are dried then milled to a free flowing meal.

2. In the dry rendering process, the tissue is ground to a particle size of about 30~40mm, and then heated in a jacketed container where mechanical agitation is provided. The water is evaporated either at atmospheric or increased pressure. The fat and solids are then separated over a screen. The fat is refined to remove any fine particles of solids remaining. The solids are pressed to remove excess fat then milled to a free flowing meal.

The final value is an average of the Australian consumption figures and these values have been used as inputs to modify CA-GREET model.

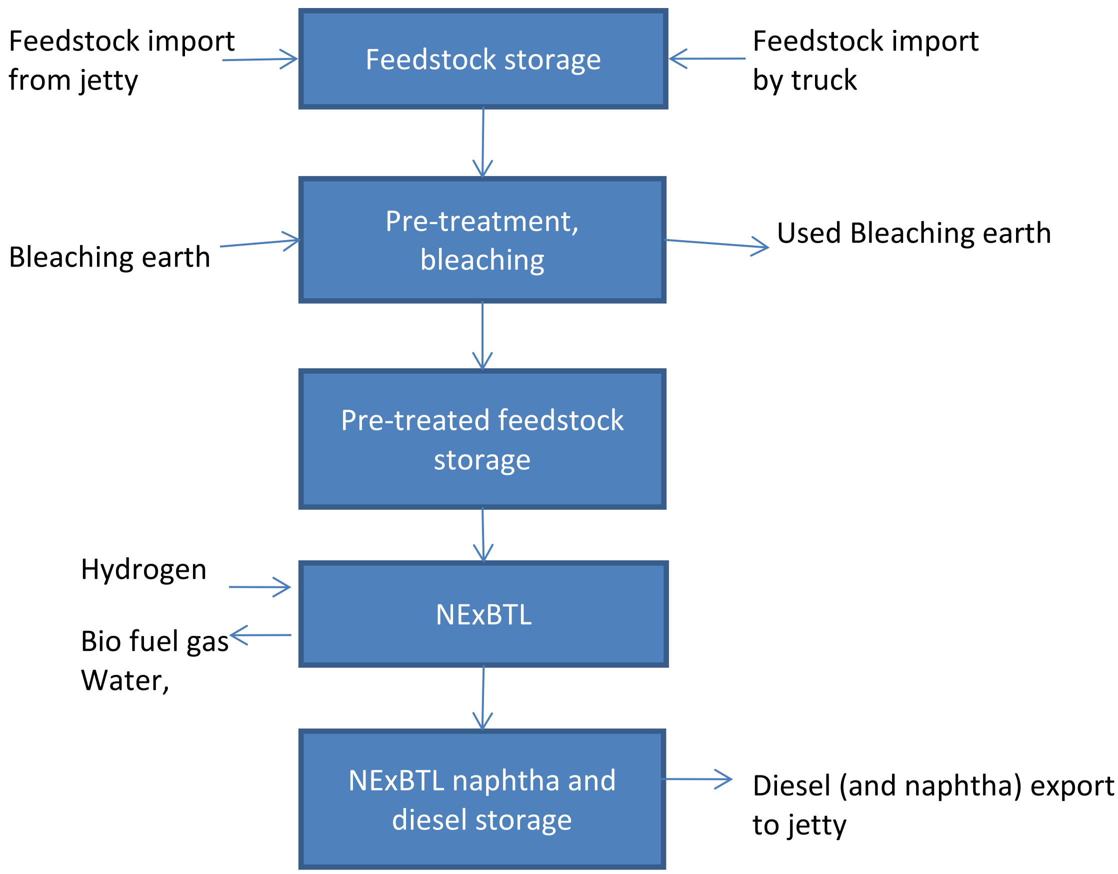
## 5 NExBTL® PROCESS OVERVIEW

The overall features of the Singapore NExBTL® Renewable Diesel production plant are shown in Figure 1. The process is comprised of a number of sub process units which are described in more detail below which are:

- Pre-treatment (impurities removal);
- Hydro treatment (oxygen removal, paraffins production and branching; propane production [high pressure and low pressure propane rich off gas])
- Stabilization (removal of residual light gases);
- Recycle (hydrogen recovered & recycled; water, carbon dioxide removal, light gases recovered)

The propane off gas from the Recycle section is used in the steam methane reformer (SMR) plant for the production of hydrogen and the propane off gas from the Stabilization section is used in a natural gas boiler to raise process steam.

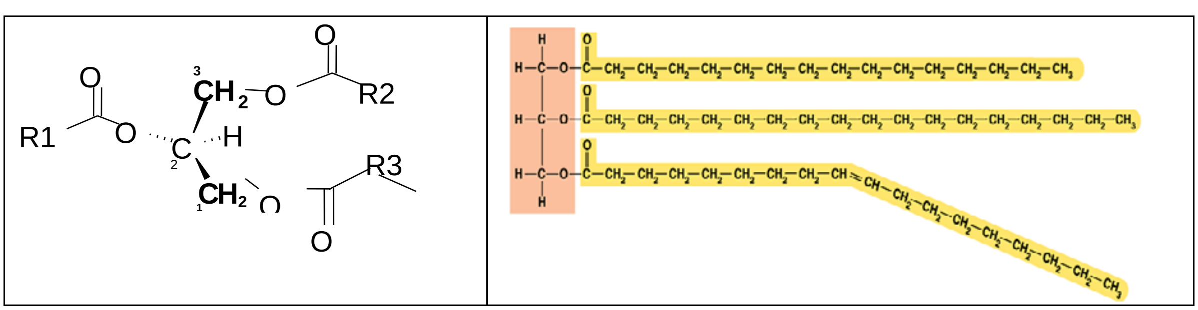
**Figure 1 NExBTL® Singapore Process Diagram**




## 6 MASS BALANCE (THEORETICAL)

The feedstocks for the process are vegetable oils and animal fats. NExBTL® Renewable Diesel plants are also able to process fatty acids such as PFAD (palm oil fatty acid distillate). Common triglyceride representations are shown below. The side chains R1, R2, R3 vary by length and are typically in the range of C14 to C18.

**Figure 2 Triglyceride molecule models**



A simplified mass balance for a model triglyceride $C_{57}H_{102}O_6$ (molecular weight 882 g/mole) is presented. Oxygen is removed as both water ($H_2O$) and as carbon dioxide ($CO_2$). The ratio depends on the catalyst and particular conditions employed. A typical ratio is shown in the example below. The equation is written without the production of bio-naphtha as only very small volumes of light hydrocarbons are formed.

A simplified mass balance of the renewable diesel process can be written as:
1.18 kg $C_{57}H_{102}O_6$ + 0.035 kg $H_2$ →1 kg RD +0.05 kg $CO_2$ +0.1 kg $H_2O$ +0.06 kg $C_3H_8$

Since there are impurities removed in the pre-treatment of purification stage which must be removed prior to processing a slightly higher amount of feed is needed than in the above equation.

## 7 DESIGN CAPACITY

The Singapore plant has a design capacity of approximately 114 tonnes / hour NExBTL® renewable diesel. Based on an annual operating hours of 8760 hours this translates into 832 000 tonnes / year. During the period in question from September 1, 2011 to August 31, 2012 the plant was operating close to full capacity producing about 740 000 t of NExBTL®.

## 8 REALIZED SINGAPORE MASS BALANCE

The Singapore plant has been operating for approximately 2 years. The plant was officially opened in March 2011. During the start-up period, the plant capacity was raised and individual process units thoroughly tested. The results of energy and mass balances during the start-up phase of a production plant are not relevant for use in GHG calculations as the plant is not operating in a steady state mode and the energy consumption and chemicals consumption are not representative of full capacity values.

The mass balance for the period of September 1, 2011 to August 31, 2012 is shown in the table below. Comparison of the realized mass balance to that calculated from reaction stoichiometry in section 3 it can be seen that the actual values are very similar to the calculated values. Combining the values of HP & LP off gases (containing bio propane) gives 0.06 t/t NExBTL®.

The carbon dioxide and water amounts are not reported in the table.

**Table 3 Mass Balance NExBTL® Singapore 01.09.2011 - 31.08.2012**

| | | t per t NExBTL® |
|---|---|---|
| Pretreatment Total Feed | | 1.21 |
| NExBTL® Unit Feed | | 1.18 |
| Hydrogen to NExBTL® Unit | | 0.038 |
| NExBTL® Unit Production and Yields | | |
| | NExBTL® Product | 1 |
| | Bio naphtha Product | 0.0052 |
| | HP propane rich off gas | 0.0505 |
| | LP propane rich off gas | 0.0096 |

# 9 FEEDSTOCK PRE-TREATMENT SECTION

The function of the pre-treatment unit (PTU) is to reduce the level of impurities in the feed to acceptable levels and thus ensure a long catalyst lifetime.

The pre-treatment unit is designed for the continuously processing of vegetable oils and fats. The pre-treatment process is based on a bleaching unit (BLU). The bleaching unit can be operated independently from the rest of the plant and the operational configuration depends on the type and quality of the feedstock to be treated.

The bleaching process begins with the addition of an acid, forming a salt and removal of the salt by precipitation. The resultant feedstock is then fed through silica and/or bleaching earth which act as adsorbents for further reduction of impurities. Spent bleaching earth is disposed off-site.

The levels of acids or bleaching earth used are in the range of 0.003 to 0.0003 kg /kg of NExBTL® Renewable Diesel.

# 10 HYDRO TREATING SECTION

## 10.1 Hydro deoxygenation (HDO)

The catalytic hydro treatment of triglycerides occurs through consecutive reactions forming three, straight chain paraffins; plus propane, water and carbon dioxide with the amounts described earlier. There is 100% conversion of triglycerides in the reactor. This reaction step is normally referred to as hydro deoxygenation or HDO.
The reaction takes place by contacting the triglycerides with hydrogen over catalysts at elevated temperatures and pressures.
The HDO hydro treating reactions are exothermic. The excess heat that is produced must be removed from the process. This excess heat is used to heat up the incoming feed. This reduces the requirement for external energy.
The gases produced during this step are fed to the Recycle section after water has been condensed out for recycle and reuse.

## 10.2 Isomerization

After the HDO step, the paraffins are branched or isomerized. Isomerization is used to improve the cold flow properties of the final fuel. The reaction is carried out in an atmosphere of hydrogen but there is negligible hydrogen consumption in this step

The liquid hydrocarbons are next fed to the diesel stabilization column.

# 11 HYDROGEN PRODUCTION SECTION

Hydrogen is produced off-site in a Steam Methane Reformer (SMR).The SMR plant is located on nearby Jurong Island and connected to the Neste Oil Singapore plant via a hydrogen pipeline network. Hydrogen consumption was approximately 0.1 MJ / $MJ_{NExBTL®}$.

Both natural gas and propane rich HP off gas are used in the SMR plant. The HP propane rich off gas is supplied in a dedicated pipeline. The natural gas used in the SMR plant is from the local natural gas network that is imported from Malaysia and Indonesia.

## 12 STABILIZATION SECTION

Product from the isomerisation reactor is routed to the stabilization column where light hydrocarbons are separated by stripping with low pressure steam. The stripping steam is generated in the waste heat boiler from condensate with heat of the diesel stabilization column bottom product. Hydrocarbons that are stripped are called LP off gas.

## 13 GAS SEPARATION AND RECYCLE SECTION

The function of this section is to separate the gas mixture into individual gas streams for use or removal and disposal. Hydrogen is returned to the process for use while the high pressure (HP) propane rich off gas is sent to a steam methane reformer (SMR) for hydrogen production and low pressure (LP) propane rich off gas is sent to a natural gas steam boiler for process steam production.

The gases are selectively and sequentially removed by first absorption or washing with an aqueous amine solution followed by amine regeneration where the individual gases are separated.

The recycle section is comprised of a number of wash columns and regeneration columns. The carbon dioxide and water streams are cleaned before releasing to the atmosphere or to the wastewater system.

Hydrogen is recovered by its selective permeation through a membrane. Hydrogen is then compressed and ready for use in the process.

## 14 CO-PRODUCT HP PROPANE OFF GAS CREDIT

In the recycle section of the Neste Oil Oyj Singapore plant, , the biogenic propane rich HP off gas generated by the process displaces an energy equivalent of natural gas (NG) that would otherwise have been consumed as both process fuel and as feedstock in the SMR. In order to calculate the greenhouse gas savings due to this HP propane rich off gas stream, this may be modelled by first assuming a NG only consumption in the SMR, that is without recycling of the off gas, and then subtracting a credit for the amount of NG displaced.

Based on the production figures for the Singapore plant during the time period in question, the propane rich HP off gas had an energy equivalent to 1.78e12 Btu which means that 1,086.2 Btu off gas is generated per pound of NExBTL®. This value is then converted into a GHG credit of 3953.48 g CO2e/MMBtu NExBTL® and further to 3.75 g CO2e/MJ NExBTL® . GHG credit per MMBtu off gas is based on natural gas carbon intensity of 71,744 gCO2e/MMBtu and propane tail pipe emissions of 2,638 gCO2e/MMBtu. Leading to a total credit of 69,106 gCO2e/MMBtu off gas.

## 15 STEAM CONSUMPTION & PRODUCTION

The Neste Oil Singapore plant is located in the Tuas industrial area which is adjacent to the Tuas power plant. The process steam used in the Neste Oil NExBTL® Singapore plant is produced in a natural gas boiler in the Tuas Power Plant and utilizes natural gas is from the natural gas network and the low pressure (LP) propane rich off gas is from the NExBTL Singapore plant. As the propane rich off gas is biogenic, only the natural gas contributes to net greenhouse gas emissions.

## 16 POWER CONSUMPTION

During the period from September 1, 2011 to August 31, 2012, electrical power consumption in the Neste Oil Singapore NExBTL® plant was 0.106 kWh/kg NExBTL or 0.0086 $MJ_{elec.}$ /$MJ_{NExBTL}$. This was purchased from the Singapore grid.

## 17 NExBTL® PHYSICAL DELIVERY

NExBTL® is transported from the production plant to a storage tank via pipeline over a distance of less than 1 mile. NExBTL® is transported for loading from the storage tank to the vessel via another pipeline over a distance of less than 1 mile.

NExBTL® is then shipped from Singapore to California discharge ports via ocean-going vessels over an average distance of 7,677 miles. Upon arrival, NExBTL® is discharged from the vessel to the onshore storage tanks via pipeline.

## 18 PATHWAY CI SUMMARY

The final carbon Intensity of the proposed pathway is summarized in the table below:

| | **Carbon Intensity in g$CO_2$e/MJ** |
|---|---|
| Tallow Production (By rendering) | 16.06 |
| Tallow Transport | 3.95 |
| Renewable Diesel Production | 10.63 |
| Renewable Diesel Transport and Distribution | 5.79 |
| Total WTT | 36.43 |
| Total TTW | 0.78 |
| Propane Rich Off-Gas Credit | -3.75 |
| **Total WTW** | **33.46** |